Presentation

on

Supercapacitor : Modeling, Simulation & Applications

by

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Overview

- Introduction
- Attractive Features of UC
- Principles, Construction & Working
- Types of Ultracapacitors
- Comparison with others
- Advantages & Applications
- Literature Survey
- 2nd thought on primary source (Battery)
- Future Scenario
- References.

Conventional Capacitor

- A capacitor (originally known as **condenser**) is a device which is used to store the charge in an electrical circuit. Basically a capacitor is made up of two conductors separated by an insulator called dielectric.

- When there is a potential difference (voltage) across the conductors, a static electric field develops across the dielectric, causing positive charge to collect on one plate and negative charge on the other plate. Energy is stored in the form of electrostatic field.

$$C = \frac{\varepsilon A}{d}$$

Ultracapacitor

- Ultracapacitor is modern electric energy storage devices with very high capacity and a low internal resistance.
- Ultracapacitors utilize high surface area electrode materials and thin dielectrics to achieve high capacitance which allows energy densities greater than those of conventional capacitors and power densities greater than those of batteries.
- Also known as Supercapacitors or double-layer capacitors or Electrochemical Capacitors.

Attractive Features

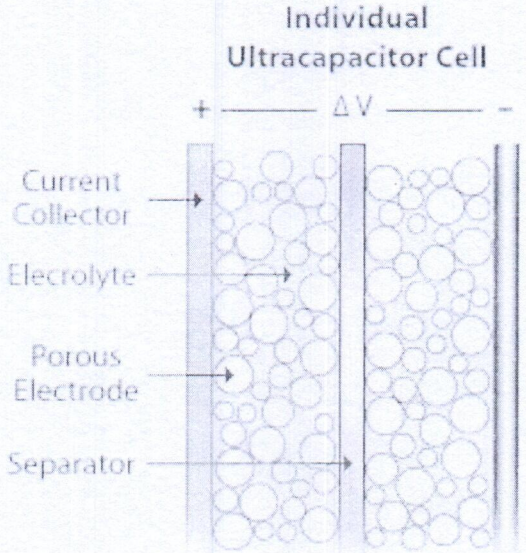
- Very high Capacitance ranging to **kilo Farads**
- No chemical reaction involved
- Much more effective at **rapid, regenerative energy storage** than chemical batteries
- Works even at **low temperatures** -40 degrees Celsius
- Almost unlimited numbers of charge-discharge cycles

Principle of Ultracapacitor

- Energy is stored in Ultracapacitor by polarizing the electrolytic solution. The charges are separated via electrode–electrolyte interface.
- Store electrical charge in a similar manner to conventional capacitors, but charges do not accumulate on conductors. Instead charges accumulate at interface between the surface of a conductor and an electrolytic solution.
- One layer forms on the charged electrode, and the other layer is comprised of ions in the electrolyte.

Construction of Ultracapacitor

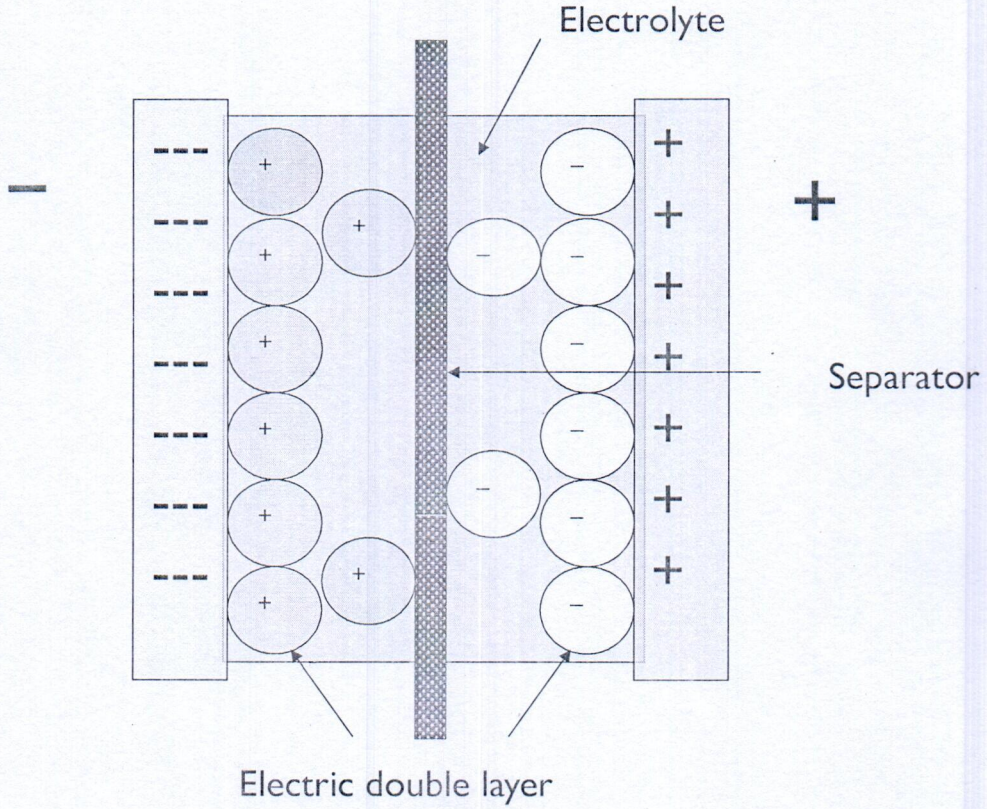
- Ultracapacitor consist of a porous electrode, electrolyte and a current collector (metal plates).
- There is a membrane, which separates, positive and negative plates called separator.



Working of Ultracapacitor

- There are two carbon sheet whose geometrical size is taken in such a way that they have a very high surface area which is separated by a separator.
- The highly porous carbon can store more energy than any other electrolytic capacitor.
- When the voltage is applied to positive plate, it attracts negative ions from electrolyte.
- When the voltage is applied to negative plate, it attracts positive ions from electrolyte.
- Therefore, there is a formation of a layer of ions on the both side of plate. This is called 'Double layer' formation.

Formation of double layer

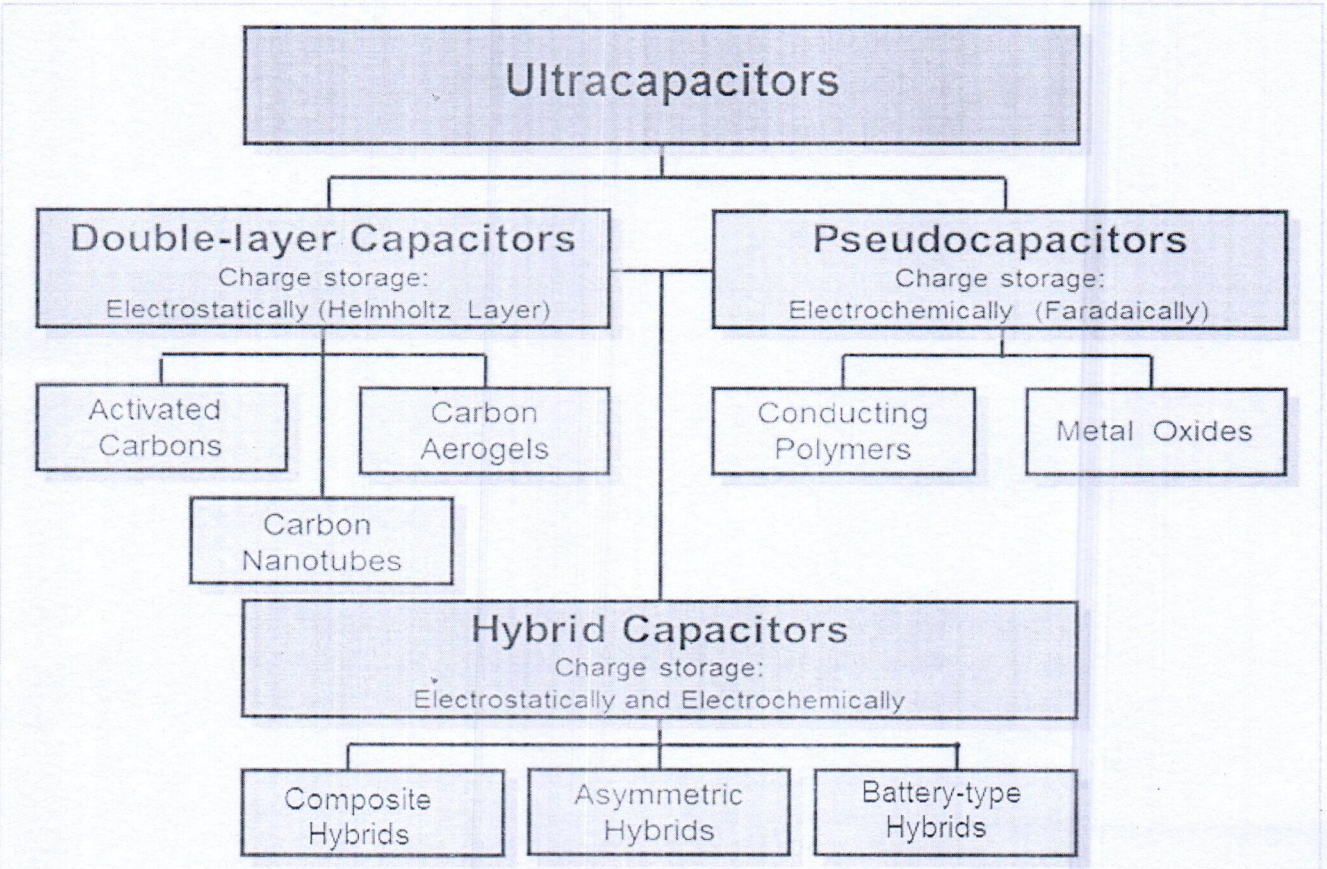


Types of Ultracapacitors

- Ultracapacitors can be divided into three general classes:
  - Electric Double Layer Capacitors
  - Pseudocapacitors
  - Hybrid Capacitors

- Each class is characterized by its unique mechanism for storing charge. These are, respectively, non-Faradic, Faradic and a combination of the two.

Classification Chart

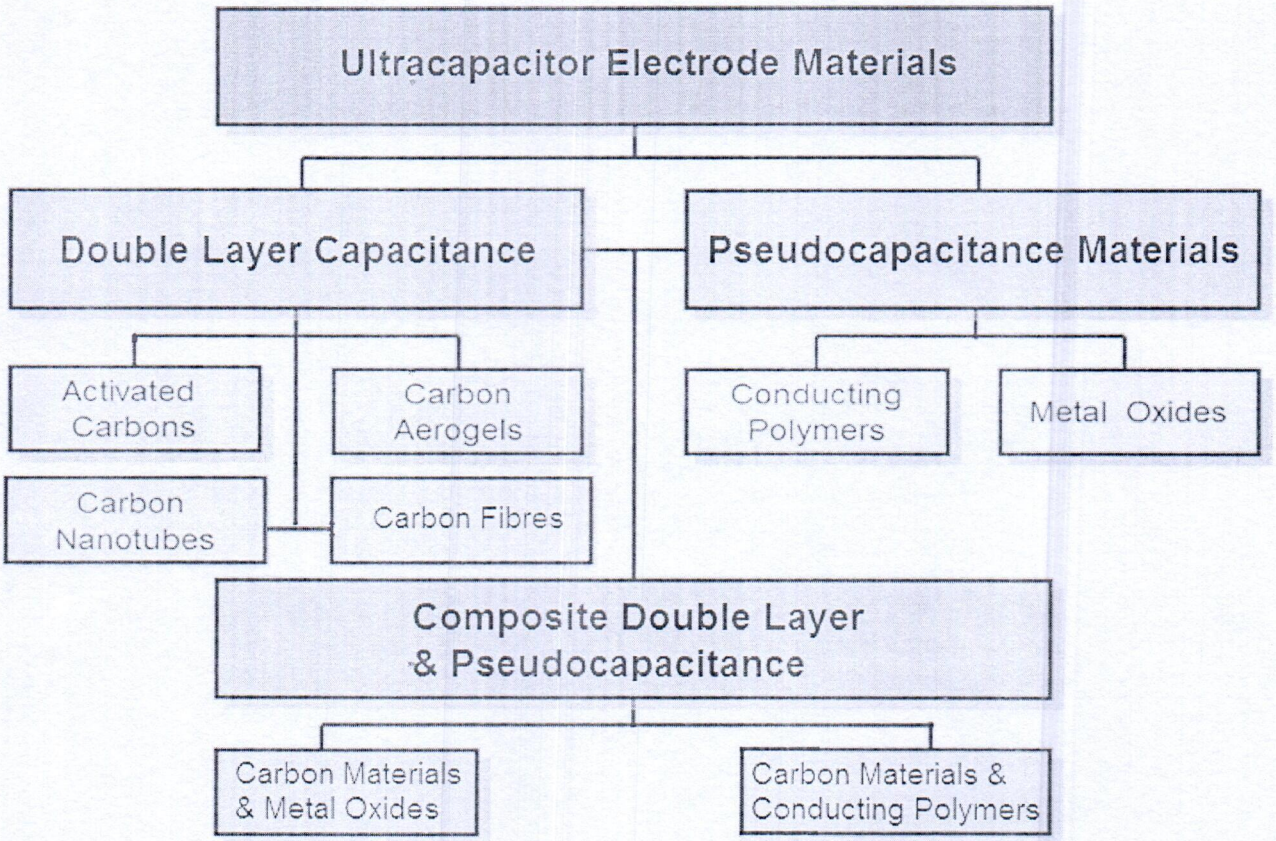


Components of Ultracapacitors

- Basic Components
  - The Electrode
  - The Electrolyte
  - The Separator

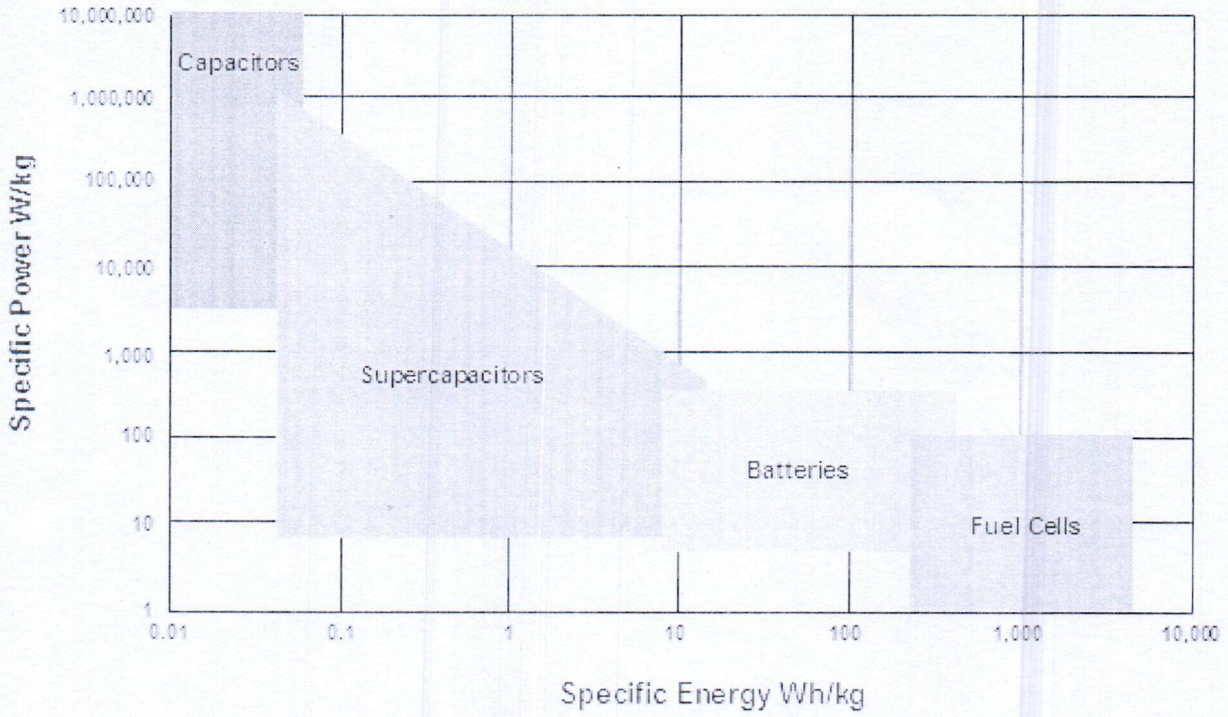
- Other Components
  - Metal Plate Current Collector
  - Outer Cans
  - Binders etc

EC Re-Classified



Ragone Plot

- Plot of Specific Power vs. Specific Energy



Comparison with Batteries

- Ultracapacitor charges within seconds whereas batteries takes hours.
- Batteries degrade within a few thousand charge-discharge cycles while Ultracapacitors can have more than 300,000 charging cycles.
- Ultracapacitor fares extremely well than batteries where high charging discharging takes place.
- Ultracapacitors are much more effective at rapid, regenerative energy storage than batteries.
- High power density.

Advantages of Ultracapacitor

- Long life: It works for large number of cycles without wear and aging.
- Rapid charging: It takes a second to charge completely.
- High power storage: stores huge energy in small volume
- Faster release: Release the energy much faster than battery.
- Low Cost: less expensive as compared to electrochemical battery.
- Low toxicity of materials used.
- High cycle efficiency (95% or more).

Applications of Ultracapacitor

- Regenerative braking.
- Military projects – starting engines of battle tanks and submarines or replacing batteries in missiles.
- Grid systems.
- Vehicles.
- Bus and Rail transport.
- Water desalination.
- A bank of Ultracapacitors releases a burst of energy to help a crane heave its load aloft; they then capture energy released during the descent to recharge.
- Can give electric cars a boost in cold weather.
- Protective devices like CB, Switch gears

Literature Survey

- [1-3] :
  - Discusses the concept of Ultracapacitor, double layer formation, working principle, applications, overview of UC along with comparisons of different types of UC

- [4,5] :
  - Identifying different types of parameters of UC for analyzing merits and demerits of UC, explains some methods to obtain UC parameters

- [6] :
  - Different electric RC models of UC are demonstrated and explains the comparison and conversion of the RC models

Literature Survey ...

- [7,8] :
  - RC series-parallel model is considered and simulated and different models are considered and simulated using different simulating tools and compared response of the UC model
- [9,10] :
  - Management of energy and limitations of using UC alone as primary source is examined
- [11,12] :
  - Different applications are discussed and compared the result of battery alone and UC-battery hybrid systems for better performance

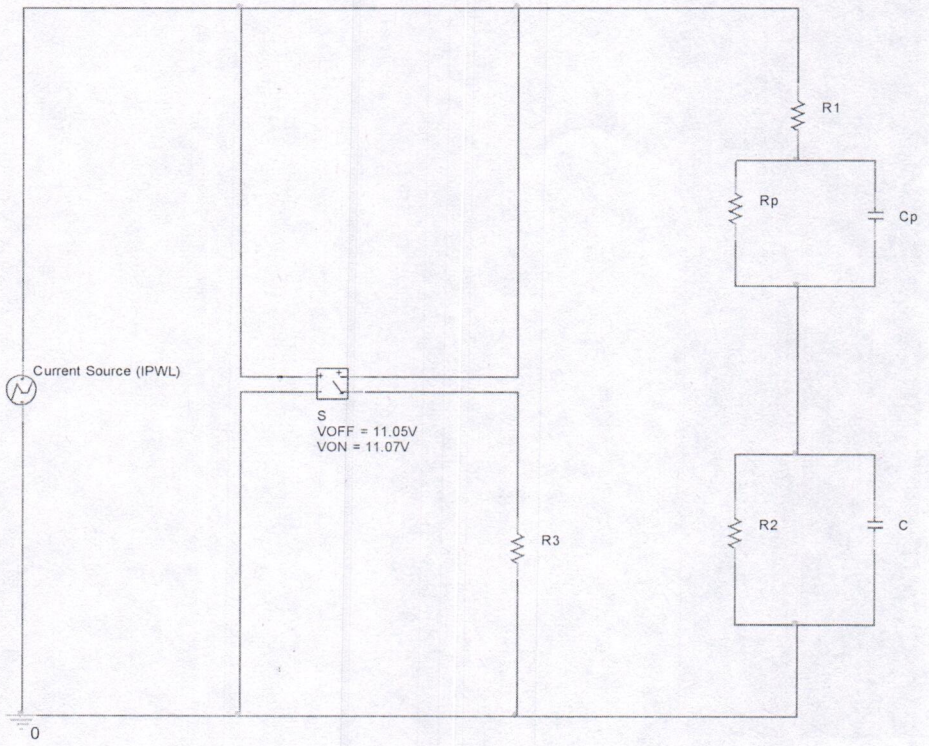
Can UC replace Battery?

- Despite many advantages of UC over conventional capacitor and electrochemical battery, UC has some demerits
  - Low energy density
  - Cannot use the full energy spectrum for some applications
  - High self-discharge as compared to electrochemical batteries
- Where ever constant energy supply source is required, UC cannot be considered primary source!

Future Scenario

- Model a UC
- Connect as UC-Battery Hybrid
- Simulate commercial UC from datasheet values
- Simulate as hybrid and compare results
- Develop energy efficient management scheme
- Apply to hybrid system and compare results of with and without management scheme
- Applications

A Simple Model [8]



Charge/Dischage : Current & Voltage

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